Gallbladder Volume and Contractility after Truncal, Selective and Highly Selective (Parietal-Cell) Vagotomy in Man

G. J. S. PARKIN, M.B., Ch.B., B.Sc., D.M.R.D., R. B. SMITH, M.B., Ch.B., D. JOHNSTON, M.D., F.R.C.S. (Edin. and Glasgow)

From The Department of Radiology and the University Department of Surgery, The General Infirmary, Leeds, Britain

TRUNCAL VAGOTOMY has been shown previously to produce dilatation of the gallbladder in man[5,9,15,17,25,26] whereas selective vagotomy does not.[15,25,26] In addition, truncal vagotomy leads to diminution in bile flow[6,10,11] and to the production of potentially-lithogenic bile[10,11,27] (in dogs) and may predispose to the formation of gallstones in man.[5,21–23] Highly selective vagotomy (HSV) is a vagotomy confined to the parietal cell mass.[1,18] As in selective vagotomy, the hepatic and celiac vagal branches are preserved, but, unlike selective vagotomy, HSV preserves the vagal nerves (of Latarjet) to the antrum of the stomach, and in consequence the addition of a drainage procedure is unnecessary. The principal advantage of HSV over truncal or selective vagotomy with a drainage procedure is that gastric emptying is better regulated, and dumping and diarrhoea greatly reduced.[14,19] However, it seemed possible that gallbladder function might also be better after HSV than after truncal vagotomy.

The purpose of this study was to compare the effects of truncal, selective and highly selective vagotomy on the gallbladder in man. The resting volume of the gallbladder, and its contraction in response to a normal meal, were measured in patients with duodenal ulcer (DU) before operation, and in patients who were in good health more than 1 year after the three types of vagotomy. In each patient, the vagotomy had been shown to be complete[13] on insulin testing soon after operation.

Method

Patients. The resting volume of the gallbladder was measured in 16 DU patients, 16 patients after truncal vagotomy and pyloroplasty (TV + P), 12 patients after bilateral selective vagotomy and pyloroplasty (SV + P) and 16 patients after HSV. A detailed comparison of the four groups of patients is presented in Table 1. In the DU patients, the diagnosis had been made on the basis of a typical history and on barium meal examination. Twelve of the 16 patients later underwent operation, at which the diagnosis was confirmed in each case. The pyloroplasties were of the Heinecke-Miculicz variety in all except two patients, in whom Finney pyloroplasties were constructed. The contraction of the gallbladder in response to a meal was followed for 90 minutes in all 16 DU patients, in 15 of 16 patients after TV + P, 4 of 12 patients after SV + P and 10 of 16 patients after HSV.

Measurement of Volume of Resting Gallbladder and of the Contraction after a Meal. The gallbladder was demonstrated by means of oral cholecystography. Ten hours before examination, the patient ingested 3 Gm. of Solubiloptin powder in water after a meal. Thereafter, he fasted, but took a further 3 gm. of Solubiloptin in water 5 hours later. Radiographs were taken in the same X-ray room, in a standard way, by one experienced radiographer. The patient lay prone on the X-ray table, and was placed carefully in the same position before each exposure was made. The distance from the X-ray tube to the film was known, and the antero-posterior thickness of the patient's body at the level of the gallbladder was measured in centimeters. These measurements permitted calculation of a correction factor[8] which was later applied to the computed volume of the gallbladder.

Submitted for publication August 29, 1972.

TABLE 1. *Comparison of the Four Groups of Patients*

	Number	Male/Female	Age: Years	Weight (KG)	Months after Operation	Insulin Test >1 Year Post-op*.
Preoperative DU	16	ALL M	49.8 ±2.8	63.8 ±2.1	—	—
Truncal V&P	16	ALL	49.3	72.7	26.9	5 −ve 3 Late +ve 1 Early +ve
		M	±2.2	±2.2	±3.8	7 ND
Selective V&P	12	10M 2F	48.5 ±4.0	61.8 ±2.6	39.8 ±3.7	ND
Highly Selective Vagotomy	16	15M	48.0	67.3	21.1	4 −ve 7 Late +ve 2 Early +ve
		1F	±2.3	±2.0	±1.3	3 ND

Numbers are arithmetic means ± one standard error.

* The insulin test had been negative in each vagotomized patient in the early postoperative period. Tests more than 1 year after vagotomy were judged negative, early-positive or late-positive[13,24] ND—not done. Patients after vagotomy were all in good health, with good-to-excellent clinical results.

Meal. After the first film had been taken to demonstrate the volume of the "resting" gallbladder (resting volume), the patient was asked to sit in a chair. He then ate a small meal consisting of one slice of a standard white loaf of bread, with 28 gm. of butter and one standard cup (180 ml.) of tea, to which were added milk and sugar to taste. Two teaspoonfuls (8 ml.) of thin barium emulsion were eaten with the meal, so that contraction of the gallbladder could be timed, not from the time of eating, but from the time at which the head of the meal first entered the duodenum. The first teaspoonful of barium was taken with the first mouthful of bread and butter.

Immediate screening of the first ten patients showed that barium entered the duodenum quickly, within 2 to 5 minutes in each case. This rapid initial emptying was seen to occur both in DU patients and in patients after TV + P and HSV. Thereafter, the assumption was made that gastric emptying would be rapid, and in all subsequent tests serial radiographs were taken at 15-minute intervals after the end of the meal for 90 minutes. In the intervals between the exposure of radiographs, the patient sat upright in a chair.

Reproducibility Studies. The resting volume of the gallbladder was measured on a second occasion in 12 patients: in three patients with DU before operation, three patients after HSV, four patients after TV + P and 2 patients after SV + P. The interval between the first and second measurements varied from 3 to 29 weeks, with a mean of 11 weeks.

Calculation of the Volume of the Gallbladder. The two-dimensional picture of the gallbladder, giving the area, was converted to a figure representing the volume of the gallbladder in milliliters, by means of the standard tables provided by de Paula e Silva.[8] This computed volume was then converted to the *corrected* volume by application of the correction factor which compensated for the magnification of the image on the film. These calculations were all performed by the radiologist (GJSP), who was kept in ignorance of the group to which each patient belonged.

The Outline of the Gallbladder was traced on to unexposed X-ray film with a fine-pointed ball-point pen. Contrary to expectation, little difficulty was experienced in deciding where Hartmann's pouch ended and cystic duct began, and two observers—radiologist and surgeon—were able to reach complete agreement on this score.

Measurement of Diameters of the Gallbladder. The method of de Paula e Silva[8] consists essentially of "slicing" the traced outline of the gallbladder into strips, each strip being 3, 5 or 8 mm. wide. The width of each strip is measured with a ruler in millimeters. This measurement gives the diameter of a cylinder, 3, 5 or 8 mm. in height, and the volume of that cylinder is read off from the standard tables provided. (The assumption is made that the gallbladder is circular on cross-section). Two observers each calculated the volumes of the same 20 gallbladders, and the volumes which they obtained were compared.

Volumes of the gallbladder in each of the four groups of patients were expressed as arithmetic means plus or minus one standard error of the mean. The significance of differences between groups was calculated using Student's *t*-test for unpaired data. Student's *t*-test for paired data was used for calculation of the significance of changes in the volume of the gallbladder after the meal.

Results

DU Patients. The mean resting volume of the gallbladder was 27 ± 1 ml., in 16 patients (Figs. 1 and 2). The range was from 15 to 36 ml. After the food, the mean volume decreased to 12 ± 2 ml., in the same 16 patients

(Fig. 2). The mean smallest single volume (irrespective of when it was recorded) was 10.9 ± 1.4 ml. If the resting volume of the gallbladder is taken as 100%, the mean smallest volume recorded after the meal was 39 ± 4%. The smallest mean volume (12.5 ml.) was reached at 45 minutes, but was little smaller than the mean volume recorded at 30 minutes (13 ml.). The difference between the volumes recorded at 30 and 45 minutes p.c. was not statistically significant ($0.4 > p > 0.3$). The mean volume of the gallbladder increased from 12 to 14 ml. between 45 and 90 minutes. This increase was not statistically significant ($0.1 > p > 0.05$).

Patients after TV + P. The mean resting volume of the gallbladder was 43 ± 4 ml., in 16 patients. Volumes ranged from 15 to 84 ml., and seven of the 16 patients had gallbladder volumes greater than 40 ml. After the meal, the mean volume decreased from 40 ± 4 to 17 ± 2 ml., in 15 patients (Figs. 1 and 2). The mean smallest volume, regardless of when it occurred, was 14.4 ± 2.2 ml., 33 ± 3% of the resting volume. The smallest mean volume was recorded at 45 minutes (Fig. 2). The mean volume decreased from 19.2 ml. at 30 minutes to 16.9 ml. at 45 minutes, then increased again to a mean of 20.5 ml. at 90 minutes. The decrease in volume between 30 and 45 minutes, and the subsequent increase in volume between 45 and 90 minutes, were both statistically significant ($p < 0.05$).

The resting volume of the gallbladder was significantly ($p < 0.01$) greater after TV + P than in DU patients before operation. It was also greater than in patients after HSV ($p < 0.01$) or SV + P ($p < 0.02$). Also, the two consecutive lowest volumes attained after the meal, in patients after TV + P, were significantly greater than the two consecutive lowest volumes in DU patients or in HSV and SV + P patients combined ($p < 0.05$).

Patients after SV + P. The mean resting volume was 27 ± 4 ml., in 12 patients. The volumes ranged from 8 to 53 ml. (Fig. 1). Three of the 12 patients had gallbladder volumes greater than 40 ml. Contractility in response to food was measured in only four patients, in whom the mean volume decreased from 41 ± 5 to 8 ± 2 ml. The mean smallest volume was 18 ± 4% of the resting volume. The smallest mean volume was recorded at 60 minutes. The resting volume of the gallbladder after SV + P was not significantly greater than that of preoperative DU patients ($p > 0.9$) and contractility was unimpaired in the four patients in whom it was measured.

Patients after HSV. The mean resting volume of the gallbladder was 28 ± 2 ml., in 16 patients. The range was from 13 to 46 ml. (Figs. 1 and 2) or from 13 to 60 ml. if the result of the second test in a reproducibility study is included. Two of the 16 patients had gallbladder volumes greater than 40 ml. (44 and 46 ml.). After the meal, the mean volume decreased from 27 ± 2 ml. to 14 ± 2

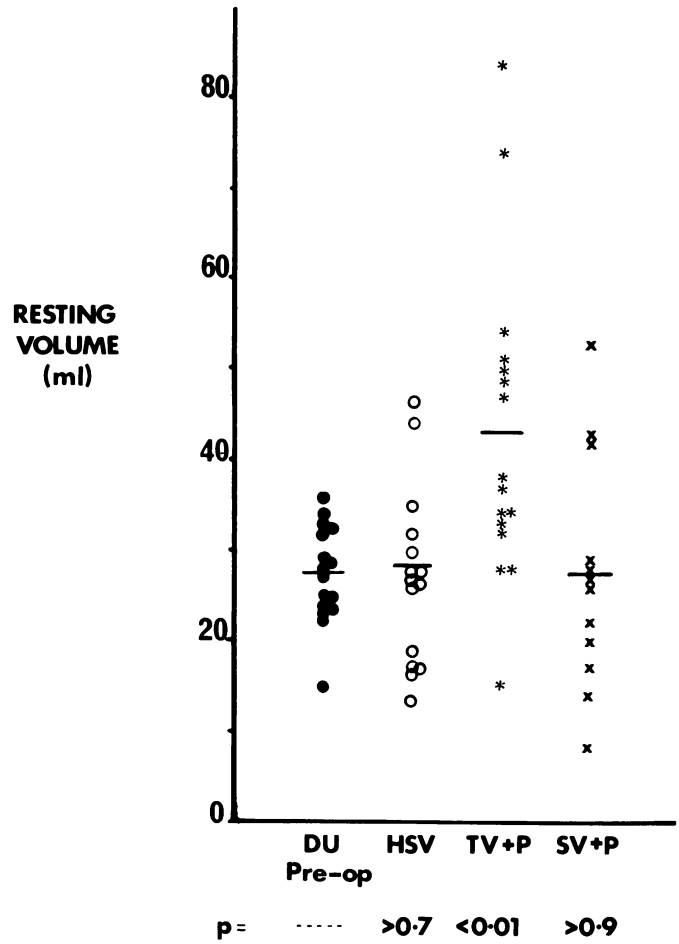

FIG. 1. Gallbladder volumes after three types of vagotomy. Resting volume of the gallbladder is shown, for each patient. Horizontal lines indicate arithmetic mean. Truncal vagotomy and pyloroplasty is followed by significant dilatation of the gallbladder: Selective vagotomy and pyloroplasty and highly selective vagotomy are not, though the gallbladder is dilated in a few individuals after these procedures.

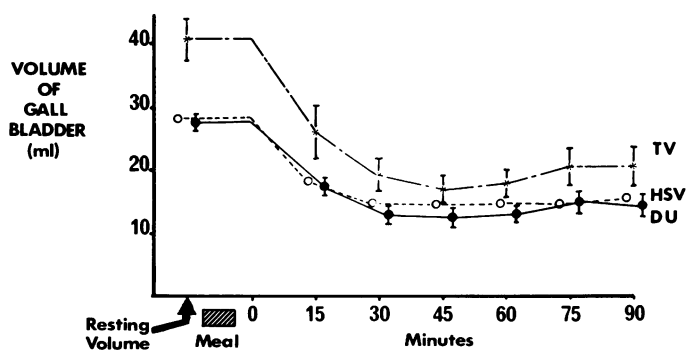

FIG. 2. Gallbladder contraction after a meal. There is no impairment of gallbladder contraction after truncal vagotomy and pyloroplasty or highly selective vagotomy. Even after maximal contraction, the volume of the gallbladder in patients after truncal vagotomy and pyloroplasty is greater than in patients after highly selective vagotomy or than in preoperative DU patients.

ml., in 10 patients. The mean smallest volume (regardless of when it occurred) was 11.7 ± 4 ml., 46 ± 5% of the initial volume. The smallest mean volume was recorded at 45 and at 75 minutes, but as in the preoperative DU patients, the smallest mean volume had almost been reached by 30 minutes. Between 45 and 90 minutes, mean gallbladder volume increased by only 0.9 ml., from 14.5 to 15.4 ml. The resting volume of the gallbladder, and its contractility in response to food, were not significantly different in patients after HSV from those which were found in DU patients before operation.

Reproducibility of Measurement of Resting Volume. Good agreement, within 20%, was obtained in seven of the 12 patients. Reproducibility was poor in five patients (Table 2). The difference between the paired measurements averaged 21% of the first measurement. The mean difference in volume between first and second tests was 7.5 ± 1.9 ml.

Correlation between Measurments Made by Two Observers. The mean (uncorrected) resting volume recorded by the first observer was 49.0 ± 4.8 ml., in 20 patients, and that recorded by the second observer in the same patients was 48.7 ± 4.7 ml. The mean difference was 0.77 ± 0.13 ml., 1.5 ± 0.2% of the value recorded by the first observer.

Discussion

The *resting volume* of the gallbladder was found to be significantly larger ($p < 0.01$) in patients who had undergone TV + P than in patients with duodenal ulcer before operation. Since the resting volume of the gallbladder is the same in DU patients as in normal subjects,[20] one may conclude that the gallbladder is abnormally large after truncal vagotomy. After HSV or SV + P, in contrast, the gallbladder was not dilated, on average, although a few individual patients were found to have dilatation of the gallbladder. This may have been due to inadvertent damage to the hepatic fibres at the time of operation and has been noted previously in an occasional patient after SV.[7,15] Our findings confirm those of previous workers who reported that the gallbladder is dilated after TV in man[5,9,15,17,25,26] and that it is not dilated after SV.[15,25,26] We have added the new information that the gallbladder is not dilated after HSV, which was the expected finding, since HSV preserves all the structures which are preserved by SV. The gallbladder has been shown to dilate progressively in the course of the first year after TV,[17] which may explain why Glanville and Duthie,[12] who measured the volume of the gallbladder less than a year after TV, did not find significant dilatation.

While it has been stated that the volume of the gallbladder approximately doubles after TV in man,[25,26] our own findings are more in keeping with those of Krause and colleagues, who reported that the mean volume of the gallbladder in 13 patients was 33 ml. before operation and 49 ml. after TV with a drainage procedure.[9] As in our own study, the increase in size of the gallbladder varied widely from patient to patient, and was less than 10% in three of the 13 patients and less than 2 ml. in four of the 13. If an arbitrary figure of 37 ml. is taken as the upper limit of normal for gallbladder volume (Fig. 1), nine of our 16 patients had dilated gallbladders after TV + P.

As is evident from the data presented in Table 1, matching of the four groups of patients was not perfect. In particular, patients after TV + P were heavier on average than preoperative patients, and the interval between operation and measurement of gallbladder size was longer in patients after SV + P than in patients after HSV or TV + P. In addition, we found that the reproducibility of the measurement of gallbladder volume left much to be desired. Nonetheless, the difference between the gallbladder volumes after TV + P and the volumes in the other three groups of patients was striking and it seems reasonable to ascribe it to the operative procedure itself, rather than to imperfections of the method.

TABLE 2. *Resting Volume of the Gallbladder: Results of Paired Tests in the Same Patients*

No.	Group	Time Interval between Tests (weeks)	1 Vol. at 1st Test ml.	2 Vol. at 2nd Test ml.	Difference ml.	Difference: Per cent of Volume at First Test
1	DU	3	23.5	24.8	1.3	5.6
2	DU	3	32.5	30.6	1.9	5.9
3	DU	8	24.7	26.8	2.1	8.4
4	HSV	11	18.9	26.5	7.6	40.1
5	HSV	29	36.4	60.3	23.9	65.6
6	HSV	10	28.5	32.8	4.3	15.3
7	SV	29	53.1	41.9	11.2	21.1
8	SV	8	42.0	29.8	12.1	28.9
9	TV	8	37.1	42.2	5.1	13.7
10	TV	9	74.1	67.1	7.0	9.5
11	TV	8	38.3	48.9	10.7	27.9
12	TV	10	34.2	31.2	3.0	8.7
Mean		11.33 wks.	36.91	38.56	7.51	20.88
±1 SEM		2.49	4.28	4.01	1.85	5.13

Although on average the resting volume of the gallbladder was significantly greater after TV + P, contractility after a meal was unimpaired (Fig. 2). That the vagally-denervated gallbladder contracts vigorously in response to the presence of fat in the intestine has been known for many years.[4,12,17,29] This is explicable on the grounds that contraction is due mainly to the release of cholecystokinin.[16] However, the smallest mean volume which the gallbladder attained after contraction (14.4 ml.) in patients after TV + P was still larger than the volumes which were recorded in patients before operation (10.9 ml) or in patients after HSV (11.7 ml). The difference (DU cf TV) was not significant ($0.2 > p > 0.1$), but if the two consecutive lowest volumes attained in each test are compared, the difference is just statistically significant (DU cf TV; $p < 0.05$: DU cf (HSV + SV), $p < 0.05$). That the volume of the gallbladder is much increased after TV, even after contraction, has been noted previously.[15,25] Thus, the residual volume of bile in the gallbladder after contraction is probably increased significantly after TV. This could predispose to the subsequent formation of gallstones.

It has been shown that stimulation of the vagi leads to an increase in bile flow, both in man[2] and in dogs.[11,28] Stimulation of bile flow in this way cannot occur after truncal vagotomy. In dogs, truncal vagotomy leads to diminution in bile flow[6,10,11] and to a change in the composition of bile, such that it is more lithogenic.[6,10,27] In man, the formation of gallstones is favored by stasis of bile, infection and an increase in the ratio of cholesterol to bile acids.[3] Several clinical studies suggest that truncal vagotomy may predispose to gallstone formation.[5,21-23] Clave and Gaspar,[5] for example found that no fewer than 21 of 92 patients after TV + P had evidence of gallbladder disease, whereas Krause showed in 1963[20] that the incidence of gallstones in patients with duodenal ulcer who have not undergone operation is little different from that which is found in normal people. In conclusion, we suggest that function of the biliary tract may be better after HSV than after truncal vagotomy, because preservation of its vagal nerve supply may prevent not only dilatation of the gallbladder, as shown in this study, but also the changes in bile flow and composition which follow truncal vagotomy. However, since these changes in bile after truncal vagotomy have been demonstrated only in the dog and not in man, further study of bile after the three types of vagotomy in man is indicated.

Summary

The resting volume of the gallbladder, and its contraction after a normal meal, were studied by means of oral cholecystography in patients with duodenal ulcer before operation, and in patients who were in good health more than 1 year after truncal, selective or highly selective (parietal-cell) vagotomy. It was found that truncal vagotomy led to significant dilatation ($p < 0.01$) of the gallbladder. Selective and highly selective vagotomy, both of which preserve the hepatic vagal fibers, were not followed by dilatation of the gallbladder.

Contractility of the gallbladder was unimpaired after each of the three types of vagotomy. It is suggested that function of the biliary tract in man may be better after highly selective vagotomy than after truncal vagotomy.

Acknowledgments

We thank Professor J. C. Goligher for his support of this project. We are indebted to Miss Ann Hawkswell of the Department of Radiology for assistance.

References

1. Amdrup, E. and Jensen, H-E.: Selective Vagotomy of the Parietal Cell Mass Preserving Innervation of the Undrained Antrum. Gastroenterology, **59**:522, 1970,
2. Baldwin, J. N., Heer, F. W., Albo, R., Peloso, O., Ruby, L. and Silen, W.: Effect of Vagus Nerve Stimulation on Hepatic Secretion of Bile in Human Subjects. Am. J. Surg., **111**:66, 1966.
3. Bouchier, I. A. D.: Gallstone Formation. Lancet, **1**:711, 1971.
4. Boyden, E. A. and Van Buskirk, C.: Rate of Emptying of Biliary Tract Following Section of Vagi or of All Extrinsic Nerves. Proc. Soc. Exp. Biol. Med., **53**:174, 1943.
5. Clave, R. A. and Gaspar, M. R.: Incidence of Gallbladder Disease after Vagotomy. Am. J. Surg., **118**:169, 1969.
6. Cowie, A. G. A. and Clark, C. G.: The Lithogenic Effect of Vagotomy. Br. J. Surg., **59**:365, 1972.
7. De Miguel, J.: Efecto de la vagotomia selectiva sin drenaje en el funcionmiento de la vesicula biliar. Rev. Esp. Enf. Ap. Digest., **31**:577, 1970.
8. De Paula e Silva, G. S.: A Simple method for Computing the Volume of the Human Gallbladder. Radiology, **52**:94, 1949.
9. Fagerberg, S., Grevsten, S., Johansson, H. and Krause, U.: Vagotomy and Gallbladder Function. Gut, **11**:789, 1970.
10. Fletcher, D. M. and Clark, C. G.: Changes in Canine Bile-Flow and Composition after Vagotomy. Br. J. Surg., **56**: 103, 1969.
11. Fritz, M. E. and Brooks, F. P.: Control of Bile Flow in the Cholecystectomized Dog. Am. J. Physiol., **204**:825, 1963.
12. Glanville, J. N. and Duthie, H. L.: Contraction of the Gallbladder before and after Total Abdominal Vagotomy. Clin. Radiol., **15**:350, 1964.
13. Hollander, F.: Laboratory Procedures in the Study of Vagotomy (with Particular Reference to the Insulin Test). Gastroenterology, **11**:419, 1948.
14. Humphrey, C. S., Johnston, D., Pulvertaft, C. N., Walker, B. E. and Goligher, J. C.: Incidence of Dumping after Truncal, Selective and Highly Selective Vagotomy Without Drainage Procedure. Br. Med. J., 3:785, 1972.
15. Inberg, M. V. and Vuorio, M.: Human Gallbladder Function after Selective Gastric and Total Abdominal Vagotomy. Acta. Chir. Scand., **135**:625, 1969.
16. Ivy, A. C. and Oldberg, E.: A Hormone Mechanism for Gallbladder Contraction and Evacuation. Am. J. Physiol., **86**: 599, 1928.

17. Johnson, F. E. and Boyden, E. A.: The Effect of Double Vagotomy on the Motor Activity of the Human Gallbladder. Surgery, **32**:591, 1952.

18. Johnston, D. and Wilkinson, A. R.: Highly Selective Vagotomy without a Drainage Procedure in the Treatment of Duodenal Ulcer. Br. J. Surg., **57**:289, 1970.

19. Johnston, D., Humphrey, C. S., Pulvertaft, C. N., Walker, B. E. and Goligher, J. C.: Vagotomy without Diarrhoea. Br. Med. J., 3:788, 1972.

20. Krause, U.: Long-term Results of Medical and Surgical Treatment of Peptic Ulcer. Acta Chir. Scand., Suppl., **310**,1963.

21. Miller, M. C.: Cholelithiasis Developing after Vagotomy: A Preliminary Report. Canad. Med. Assoc. J., **98**:350, 1968.

22. Nielsen, J. R.: Development of Cholelithiasis Following Vagotomy. Surgery, **56**:909, 1964.

23. Nobles, E. R.: Vagotomy and Gastroenterostomy: 15-Year Follow-up of 175 Patients. Am. Surg., **32**:177, 1966.

24. Ross, B. and Kay, A. W.: The Insulin Test after Vagotomy. Gastroenterology, **46**:379, 1964.

25. Rudick, J. and Hutchison, J. S. F.: Effects of Vagal Nerve Section on the Biliary System. Lancet, **1**:579, 1964.

26. Rudick, J. and Hutchison, J. S. F.: Evaluation of Vagotomy and Biliary Function by Combined Oral Cholecystography and Intravenous Cholangiography. Ann. Surg., **162**:234, 1965.

27. Schein, C. J., Rosen, R. G., Warren, A. and Gliedman, M. L.: A Vagal Factor in Cholecystitis. Surgery, **66**:345, 1969.

28. Tanturi, C. A. and Ivy, A. C.: On the Existence of Secretory Nerves in the Vagi for Reflex Excitation and Inhibition of Bile Secretion. Am. J. Physiol., **121**:270, 1938.

29. Whitaker, L. R.: The Mechanism of the Gallbladder. Am. J. Physiol., **78**:411, 1926.

30. Wilkinson, A. R. and Johnston, D.: Effect of Truncal, Selective and Highly Selective Vagotomy in Man on Gastric Emptying of Food-and-barium. Br. J. Surg., **59**:308, 1972.